Status of the SW Surface-Only Flux Algorithms

David P. Kratz[1], Shashi K. Gupta[2],
Anne C. Wilber[2], Victor E. Sothcott[2],
and P. Sawaengphokhai[2]

[1]NASA Langley Research Center
[2]Science Systems and Applications, Inc.

Twenty First CERES-II Science Team Meeting

Hampton, Virginia
22 April 2014

Background (Page 1)

CERES uses several surface-only flux algorithms to compute SW and LW surface fluxes in conjunction with the detailed model used by SARB. These algorithms include:

LPSA/LPLA:
Langley Parameterized SW/LW Algorithm

		Model A	Model B	Model C
SW	Clear	Li et al.	LPSA	--
	All-Sky	--	LPSA	--
LW	Clear	Inamdar and Ramanathan	LPLA	Zhou-Cess
	All-Sky	--	LPLA	Zhou-Cess

SOFA References:

SW A: Li et al. (1993): *J. Climate*, **6**, 1764-1772.
SW B: Darnell et al. (1992): *J Geophys. Res.*, **97**, 15741-15760.
SW B: Gupta et al. (2001): *NASA/TP-2001-211272*, 31 pp.
LW A: Inamdar and Ramanathan (1997): *Tellus,* **49B**, 216-230.
LW B: Gupta et al. (1992): *J. Appl. Meteor.,* **31**, 1361-1367.
LW C: Zhou et al. (2007): *J. Geophys. Res.*, **112**, D15102.
SOFA: Kratz et al. (2010): *J. Appl. Meteor. Climatol.*, **49**, 164-180.
SOFA: Gupta et al. (2010): *J. Appl. Meteor. Climatol.,* **49**, 1579-1589.
FLASH SSF: Kratz et al. (2014): *J. Appl. Meteor. Climatol.*, **53**, 1059-1079.

Background (Page 2)

- The SOFA LW & SW Models are based on rapid, highly parameterized TOA-to-surface transfer algorithms to derive surface fluxes.
- LW Models A & B as well as SW Model A were incorporated at the start of the CERES project.
- SW Model B was adapted for use in the CERES processing shortly before the launch of TRMM.
- The Edition 2B LW & SW surface flux results underwent extensive validation (See: Kratz et al. 2010).
- The ongoing validation process has already led to improvements to the LW models (Gupta et al., 2010).
- LW Model C (Zhou et al., 2007) was introduced in Edition 4 processing to maintain two independent LW algorithms after the CERES Window Channel is replaced in future versions of the CERES instrument (RBI).

Current Status of Improvements to the Surface-Only Flux Algorithms

SW Model Improvements: 1) Replacing the ERBE albedo maps with Terra maps greatly improved the SW retrievals, most notably for polar regions. 2) Replacing the original WCP-55 aerosols properties with monthly MATCH/OPAC datasets while also replacing the original Rayleigh molecular scattering formulation with the Bodhaine et al. (1999) model significantly improved SW surface fluxes for clear conditions. 3) To account for the short term aerosol variability we have incorporated daily MATCH aerosol data into Edition 4. 4) Using a revised empirical coefficient in the cloud transmission formula has improved the SW surface fluxes for partly cloudy conditions. 5) Work continues on the improvement of the cloud transmission method for the new Edition 4 clouds.

LW Model Improvements: 1) Constraining the lapse rate to 10K/100hPa (roughly the dry adiabatic lapse rate) improved the derivation of surface fluxes for conditions involving surface temperatures that greatly exceeded the overlying air temperatures, see Gupta et al. (2010). 2) Limiting the inversion strength to -10K/100hPa for the downward flux retrievals provided the best results for cases involving surface temperatures that were much below the overlying air temperatures (strong inversions).

SW and LW Model Improvements: 1) The availability of ocean buoy measurements is expected to allow for improved surface flux retrievals by providing validation over ocean regions.

Parameterized models for fast computation of surface fluxes for both CERES and FLASHFlux

Dataset	CERES 2B	CERES 4A
Clear-Sky TOA albedo Terra	48 month ERBE	70 month Terra
Clearr-Sky TOA albedo Aqua	46 month Terra	70 month Terra
Clear-Sky Surf. albedo	46 month Terra	70 month Terra
TOA to Surface albedo transfer	Instantaneous	Monthly average
Spec. Corr. Coef.	CERES 2B	CERES 3A
Cos (sza) dependence of Surface Flux	LPSA	Briegleb-type
Cloud Algorithm Terra	Terra Ed2	Terra/Aqua Ed4
Cloud Algorithm Aqua	Aqua Ed2	Terra/Aqua Ed4
SW aerosol dataset	WCP-55	MATCH/OPAC
Rayleigh Treatment	Original LPSA	Bodhaine et al (1999), JAOT.
Ozone Range Check	0 to 500 DU	0 to 800 DU
Twilight cutoff		New
Cloud transmission empirical coefficient	0.80	0.75
LW high temperature surface correction	No	Maximum Lapse Rate 10K/100hPa
LW Inversion correction	No	Maximum Inversion Strength -10K/100hPa

Current Status of Improvements to the Surface-Only Flux Algorithms

SW Model Improvements: 1) Replacing the ERBE albedo maps with Terra maps greatly improved the SW retrievals, most notably for polar regions. 2) Replacing the original WCP-55 aerosols properties with monthly MATCH/OPAC datasets while also replacing the original Rayleigh molecular scattering formulation with the Bodhaine et al. (1999) model significantly improved SW surface fluxes for clear conditions. 3) To account for the short term aerosol variability we have incorporated daily MATCH aerosol data into Edition 4. 4) Using a revised empirical coefficient in the cloud transmission formula has improved the SW surface fluxes for partly cloudy conditions. 5) Work continues on the improvement of the cloud transmission method for the new Edition 4 clouds.

LW Model Improvements: 1) Constraining the lapse rate to 10K/100hPa (roughly the dry adiabatic lapse rate) improved the derivation of surface fluxes for conditions involving surface temperatures that greatly exceeded the overlying air temperatures, see Gupta et al. (2010). 2) Limiting the inversion strength to -10K/100hPa for the downward flux retrievals provided the best results for cases involving surface temperatures that were much below the overlying air temperatures (strong inversions).

SW and LW Model Improvements: 1) The availability of ocean buoy measurements is expected to allow for improved surface flux retrievals by providing validation over ocean regions.

Parameterized models for fast computation of surface fluxes for both CERES and FLASHFlux

Dataset	CERES 3A	CERES 4A
Clear-Sky TOA albedo Terra	70 month Terra	70 month Terra
Clearr-Sky TOA albedo Aqua	70 month Terra	70 month Terra
Clear-Sky Surf. albedo	70 month Terra	70 month Terra
TOA to Surface albedo transfer	Monthly average	Monthly average
Spec. Corr. Coef.	CERES 3A	CERES 3A
Cos (sza) dependence of Surface Flux	Briegleb-type	Briegleb-type
Cloud Algorithm Terra	Terra Ed2	Terra/Aqua Ed4
Cloud Algorithm Aqua	Aqua Ed2	Terra/Aqua Ed4
SW aerosol dataset	WCP-55	MATCH/OPAC
Rayleigh Treatment	Original LPSA	Bodhaine et al (1999), JAOT.
Ozone Range Check	0 to 800 DU	0 to 800 DU
Twilight cutoff	New	New
Cloud transmission empirical coefficient	0.80	0.75
LW high temperature surface correction	Maximum Lapse Rate 10K/100hPa	Maximum Lapse Rate 10K/100hPa
LW Inversion correction	Polar regions and ps < 700 mb excluded	Maximum Inversion Strength -10K/100hPa

Status of SW Model Improvements

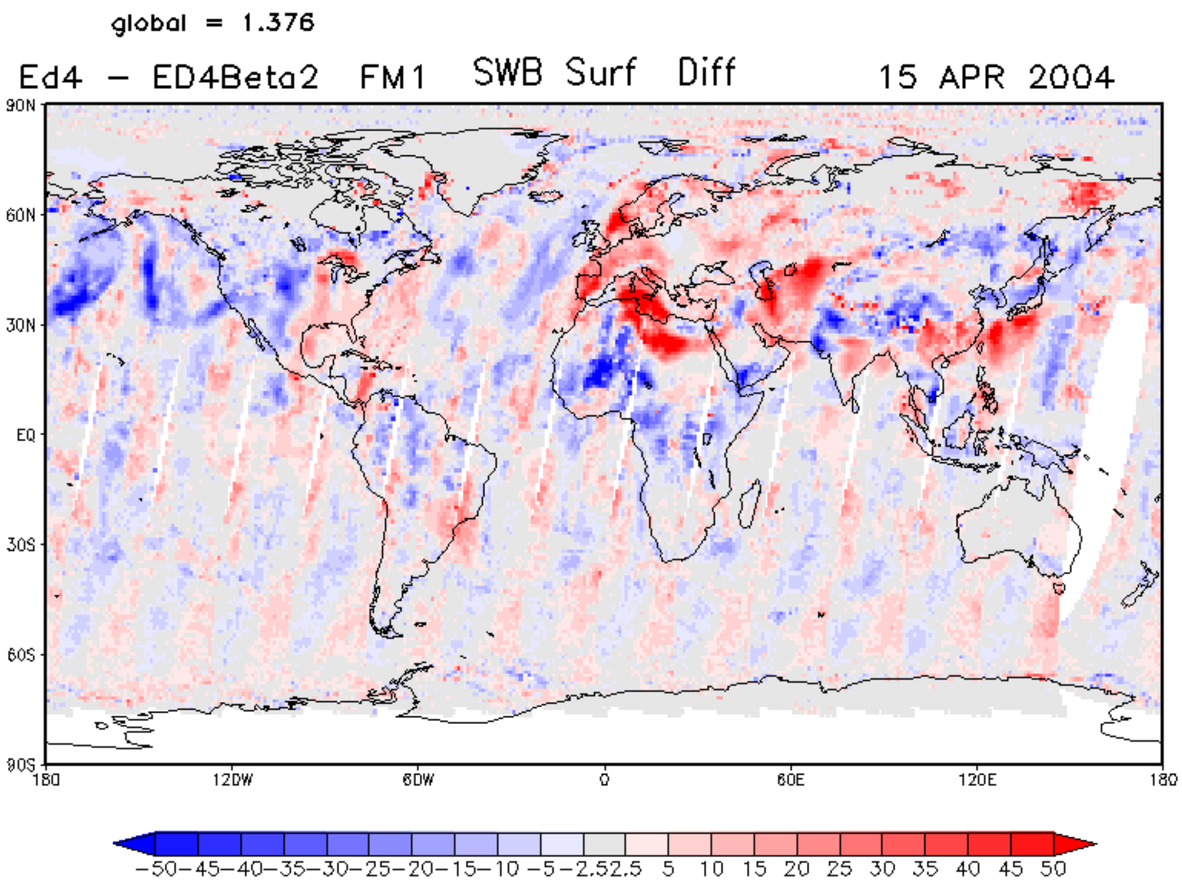
Simultaneously replacing the original WCP-55 aerosols with the MATCH aerosols, and the original Rayleigh molecular scattering formulation with an improved Rayleigh molecular scattering formulation has significantly improved the surface SW flux calculations for clear through partly cloudy sky conditions.

To account for the short term variability of aerosol properties, we have incorporated the daily aerosol properties into SW Model B.

Results for the mostly cloudy to overcast conditions showed some improvement by revising the a_0 coefficient but strongly suggest that further work on the cloud transmittance calculation is necessary. Our attention is currently focused on developing a an empirical method to account for the cloud transmittance.

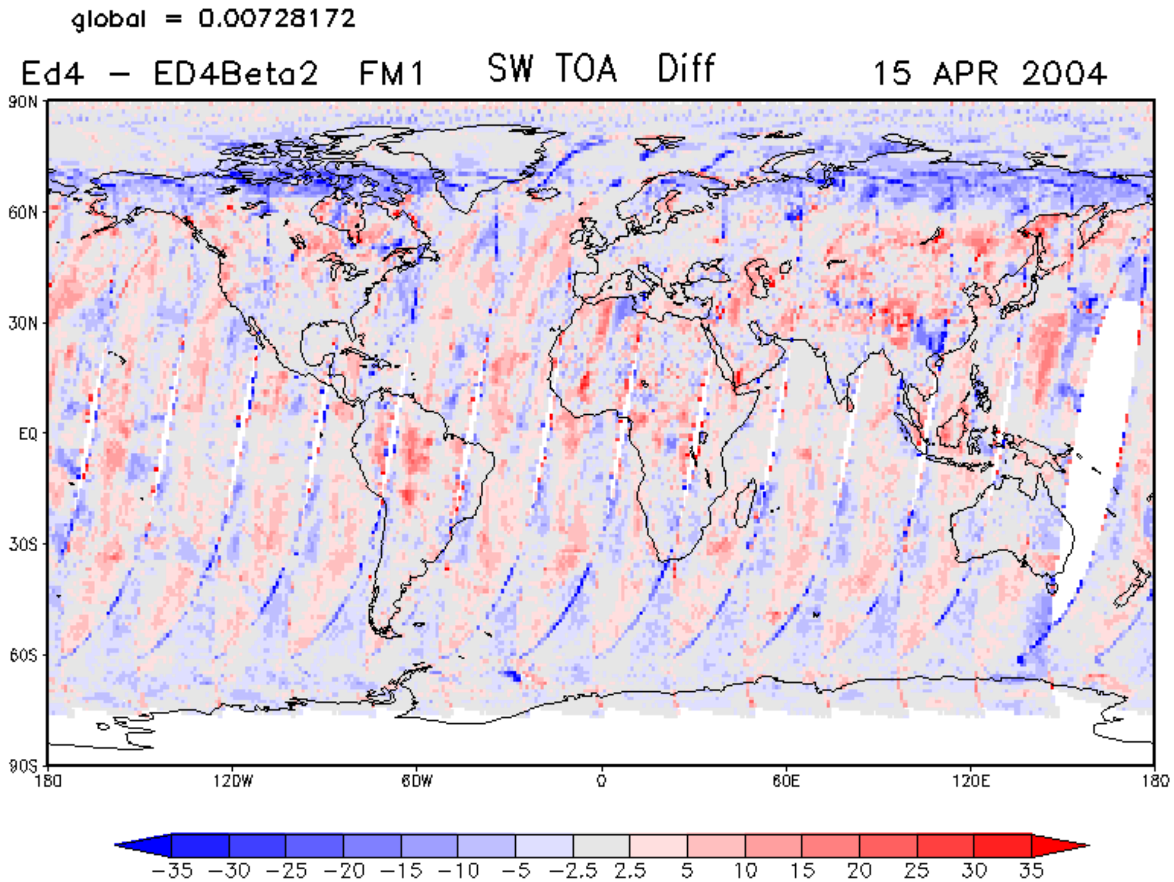
For Edition 4, ADMs and MATCH aerosols have been revised.

SWB Surface Ed4 – Ed4 β2



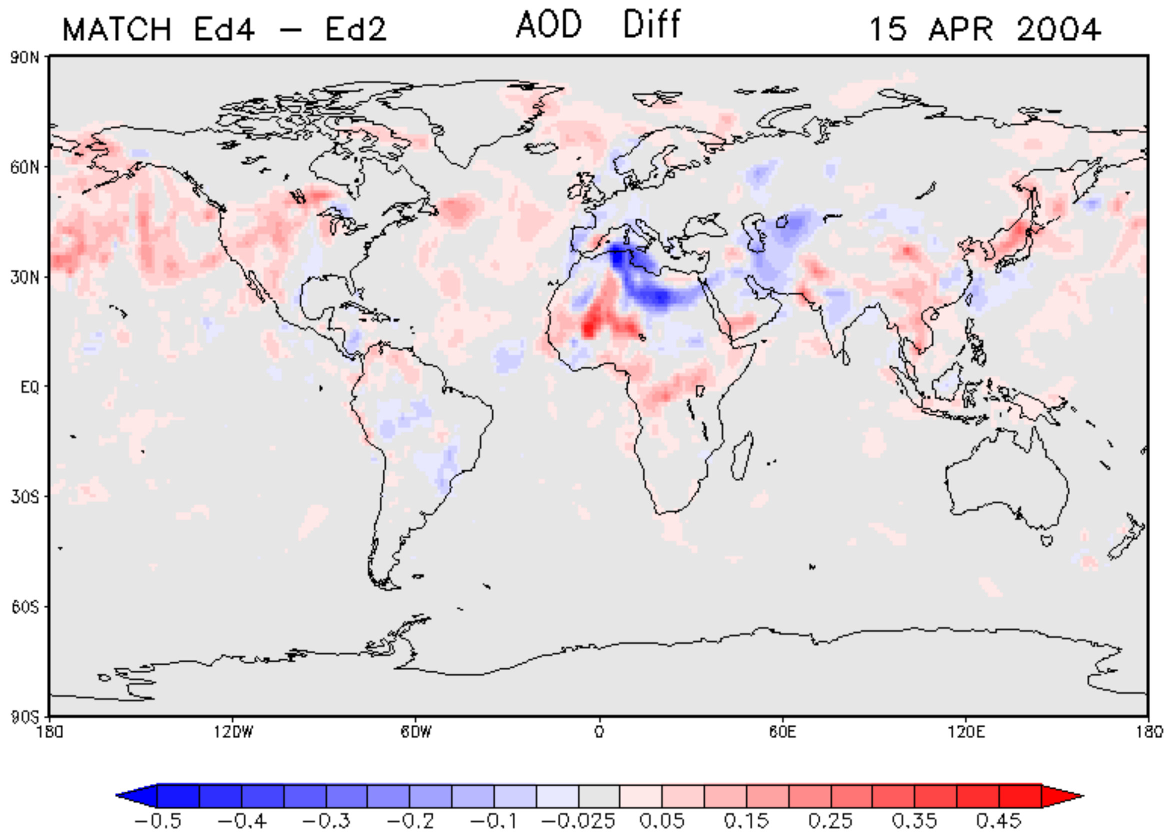
Differences due to combined changes in ADMs and MATCH aerosols

Differences in SW TOA due to revised ADMs



Change in Ed4 ADMs alters TOA Flux, which alters Surface Flux

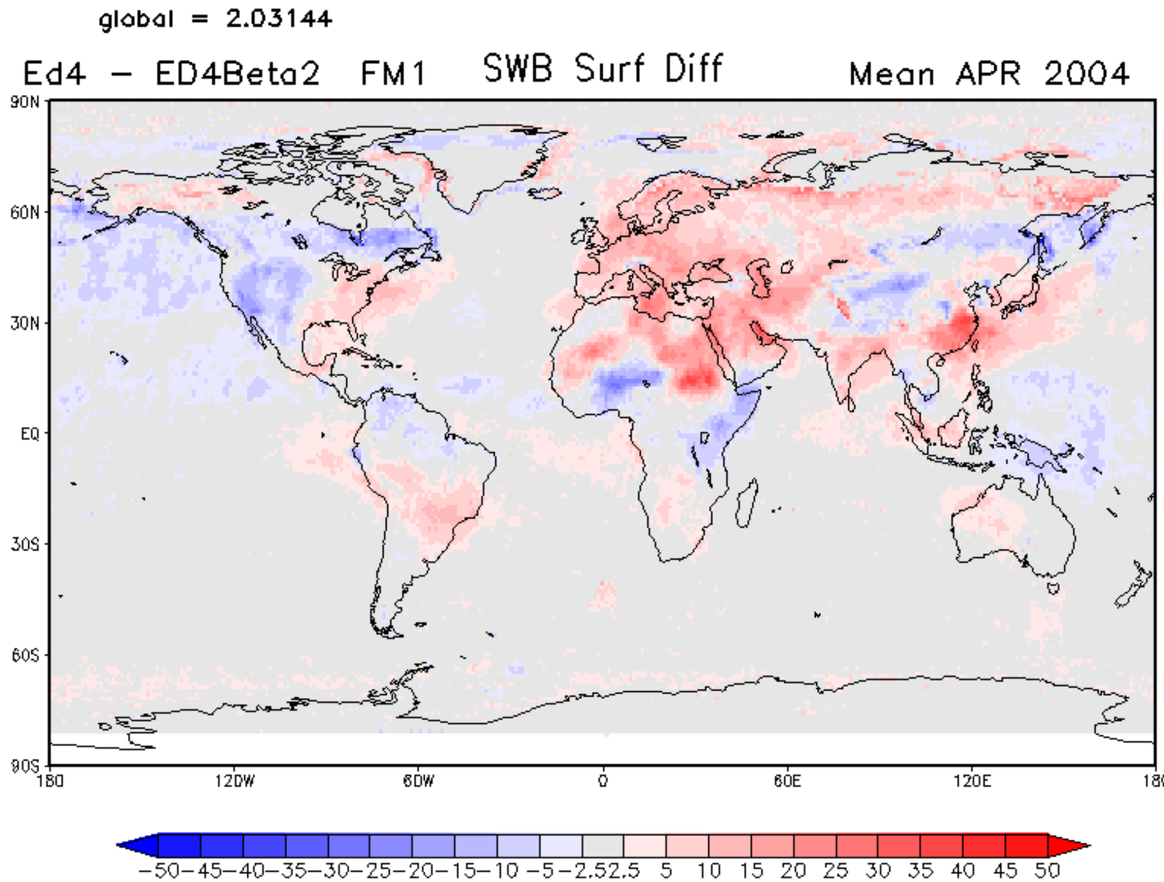
Differences in AOD, MATCH Ed4 – Ed2



CERES Ed4 uses MATCH Ed4 aerosols
CERES Ed4β2 uses MATCH Ed2 aerosols

Change to Ed4 Match Aerosols alters SWB surface flux

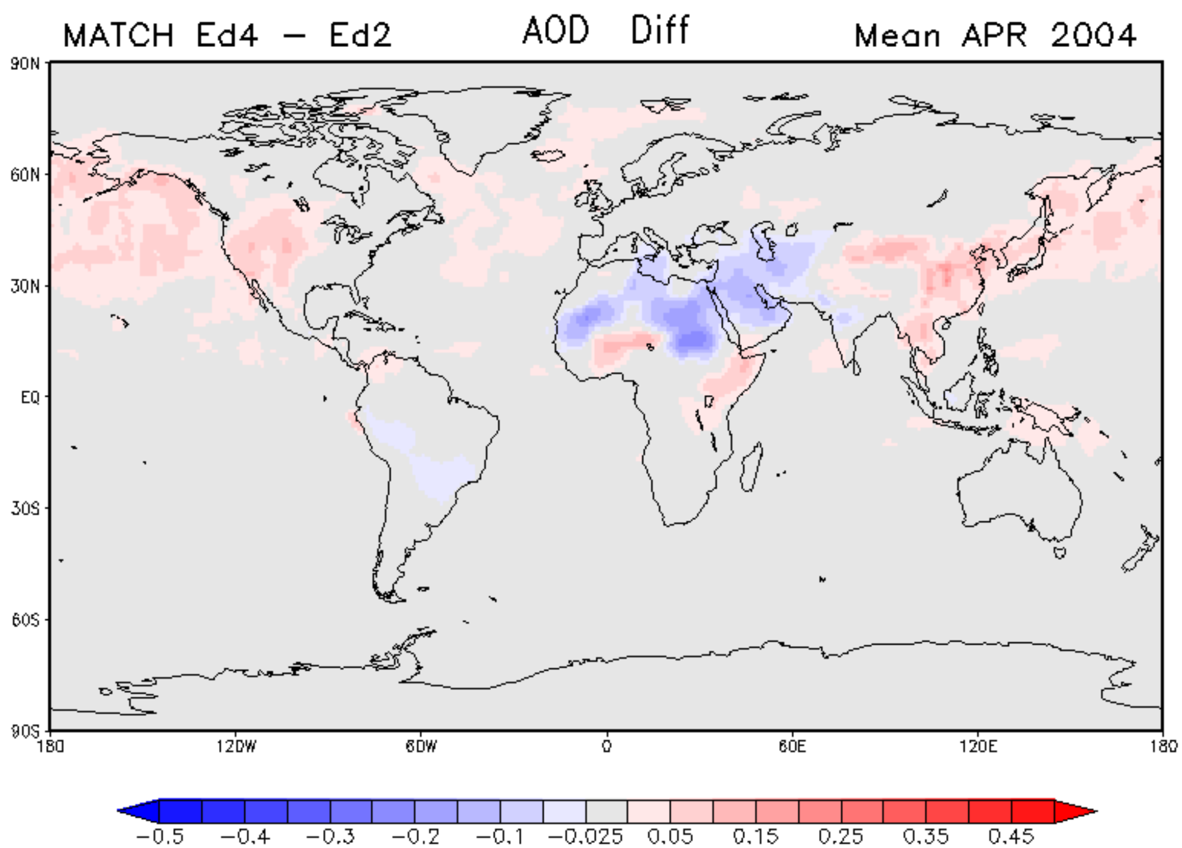
Monthly Mean Surface Differences SWB Ed4 – Ed4 β2



Monthly results average out rapidly varying differences to show persistent differences

Differences due to combined changes in ADMs and MATCH aerosols

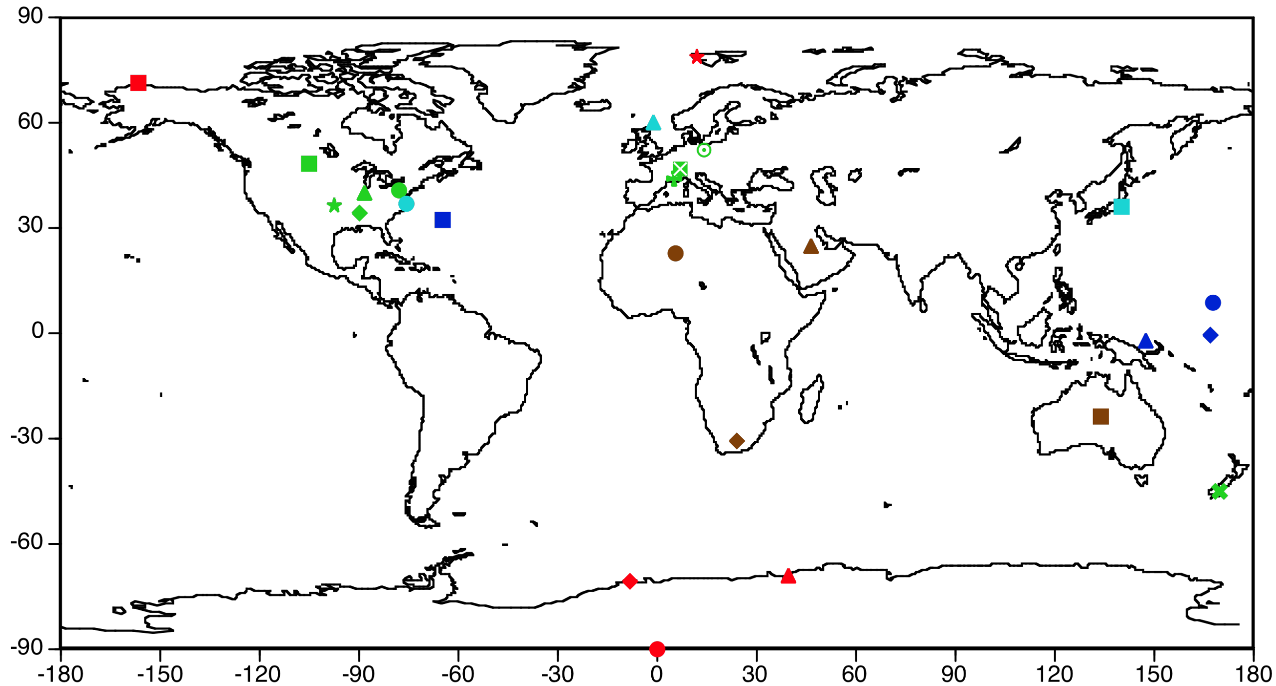
Monthly Mean Difference for AOD



CERES Ed4 uses Match Ed4 aerosols
CERES Ed4β2 uses Match Ed2 aerosols

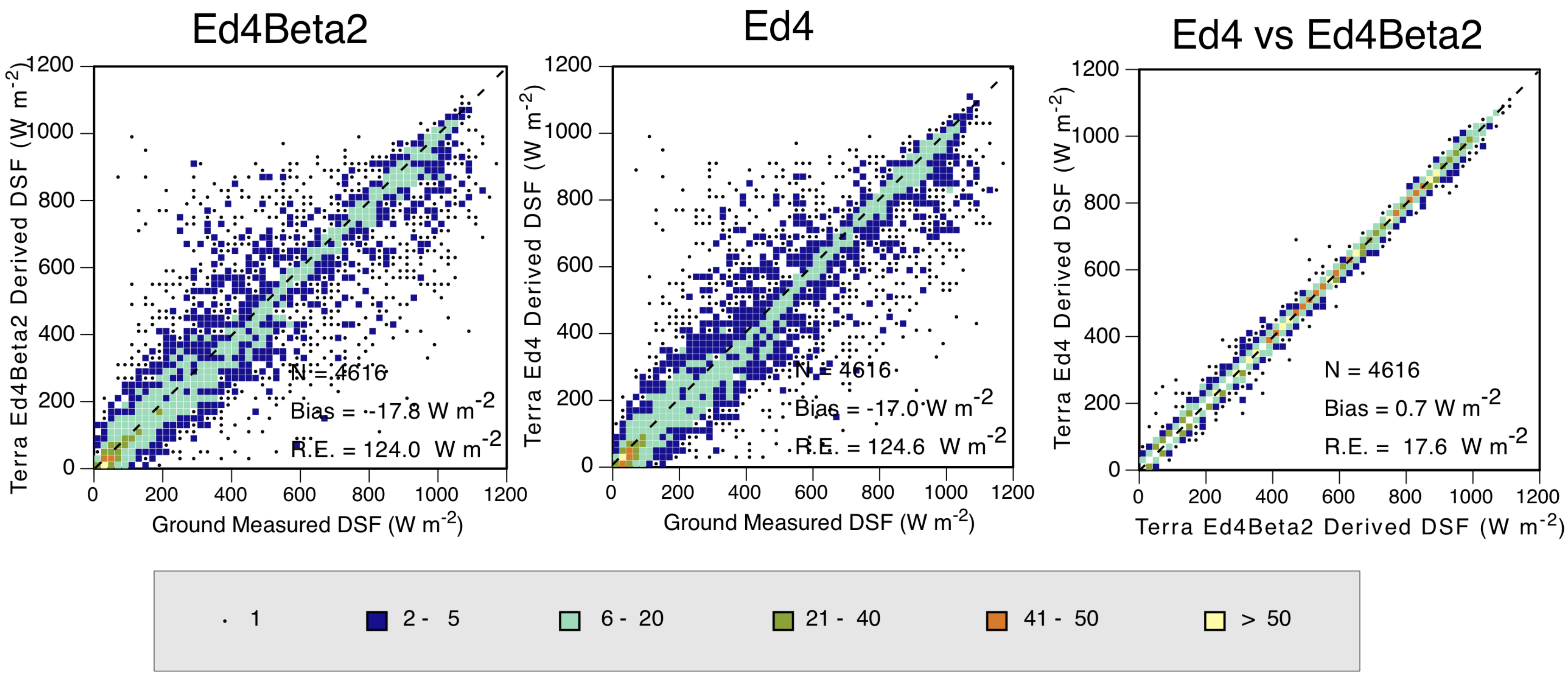
Change to Ed4 Match Aerosols alters SWB surface flux

Surface Sites Available for Validation of Ed 4



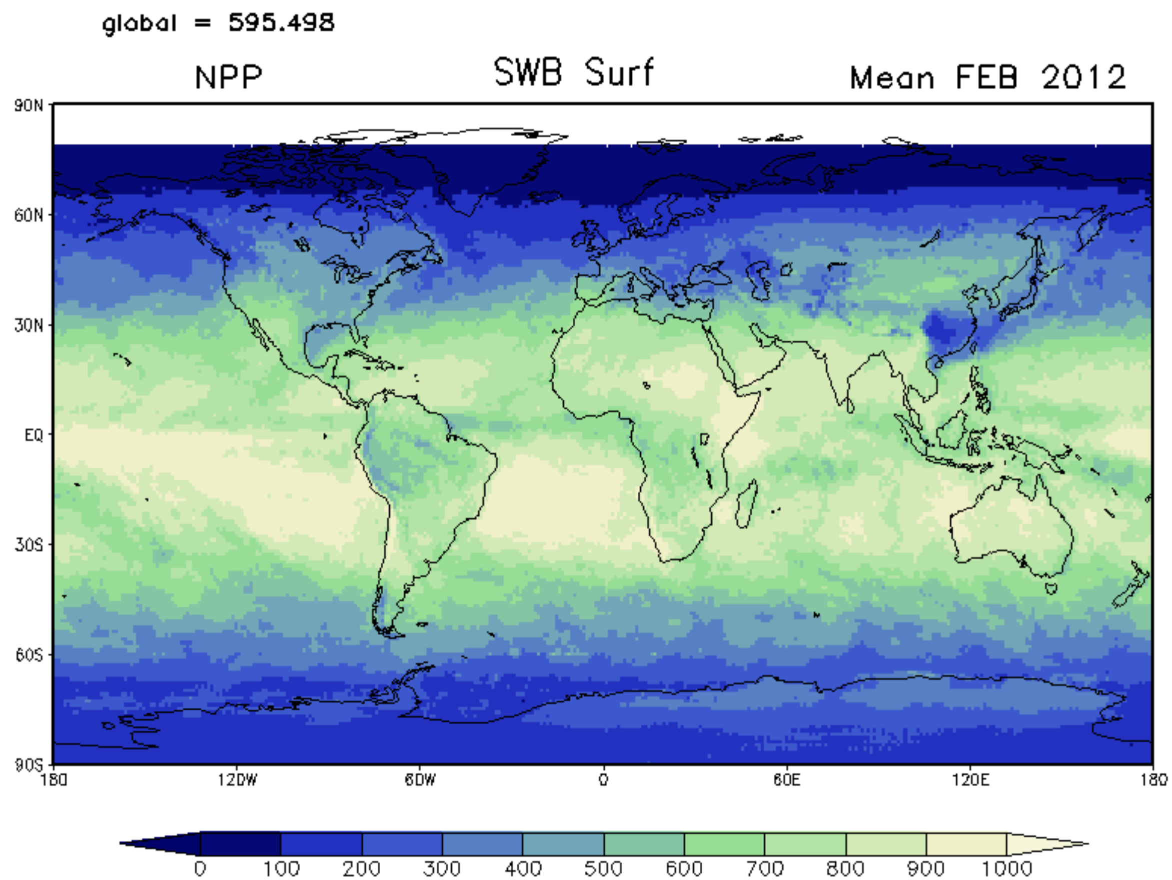
- 48.31N, 105.10W Fort Peck, MT
- 40.72N, 77.93W Penn State, PA
- 40.05N, 88.37W Bondville, IL
- 34.25N, 89.87W Goodwin Creek, MS
- 36.60N, 97.48W SGP ARM
- 45.03S, 169.7E New Zealand
- 44 N, 5.1E Carpentras, FR
- 46.82N, 6.9W Payerne, Switzerland
- 52.22N, 14.1W Lindenberg, Germany
- 32.30N, 64.77W Bermuda
- 8.72N, 167.72E Kwajalein
- 2.06S, 147.42 E Manus
- 0.52S, 166.9 E, Nauru
- 36.05N, 140.13E Tatano
- 36.9N, 75.71W Ches Light
- 60.13N, 1.2E Lerwick, UK
- 71.32N, 156.61W Barrow, AK
- 90.00S, 0.00 South Pole
- 69.00S, 39.58E Syowa
- 70.65S, 8.25W Georg von Neumayer
- 78.9N, 11.95E Ny Alesund
- 23.70S, 133.87E Alice Springs
- 22.78N, 5.52E Algeria
- 24.91N, 46.4E Saudi Solar Village
- 30.67S, 24.0W, De Aar

Global 2004 Terra SWB Ground Validation



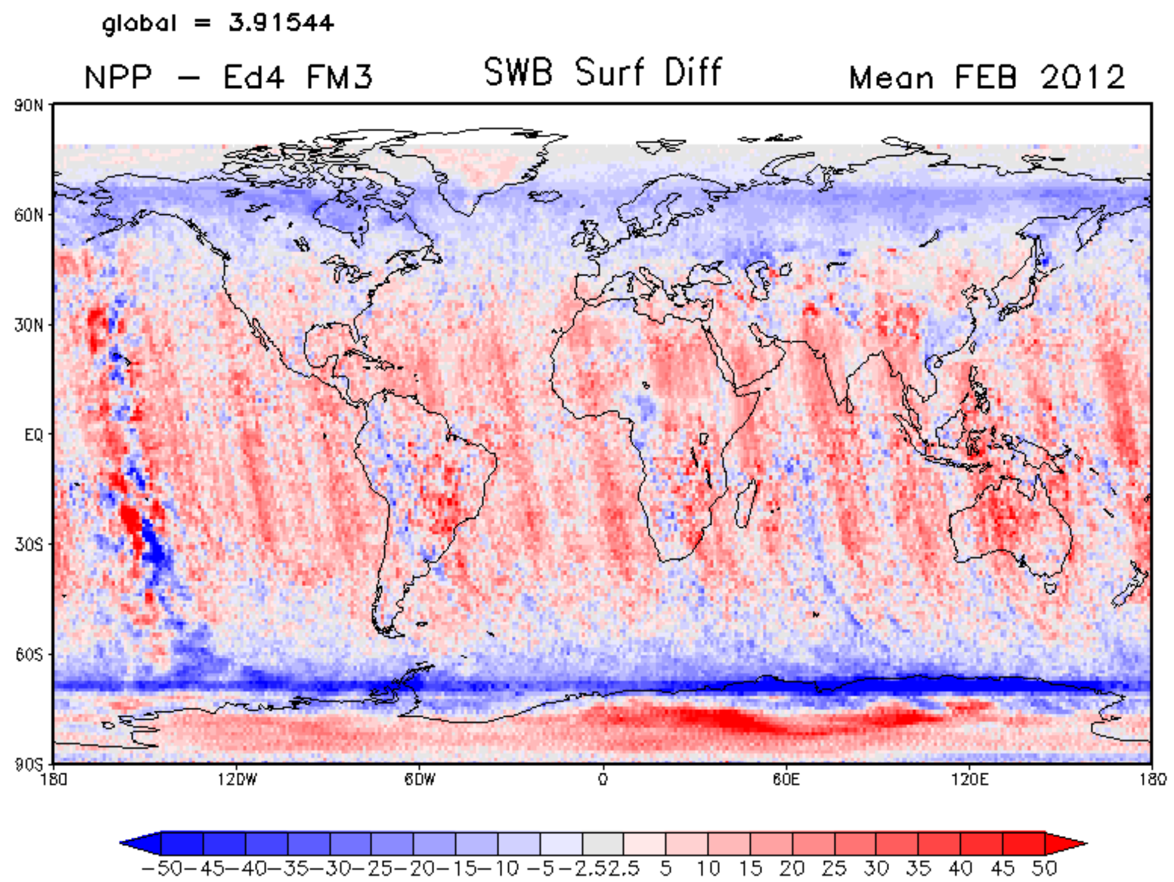
While there are differences in SWB footprint results due to differences in the input data, overall the stats changed little over the globe for the year.

SWB Surface Fluxes from NPP FM5



NPP FM5 SWB surface fluxes

SWB Surface Differences NPP FM5 minus Aqua FM3



Differences between FM5 and FM3 SWB surface fluxes

Reminder: Results of LW Model Improvements

For the condition involving surface temperatures that greatly exceed the overlying air temperatures, constraining the lapse rate to 10K / 100hPa (roughly the dry adiabatic lapse rate) has significantly improved the results for both MOA and CWG T_s, see Gupta et al. (2010).

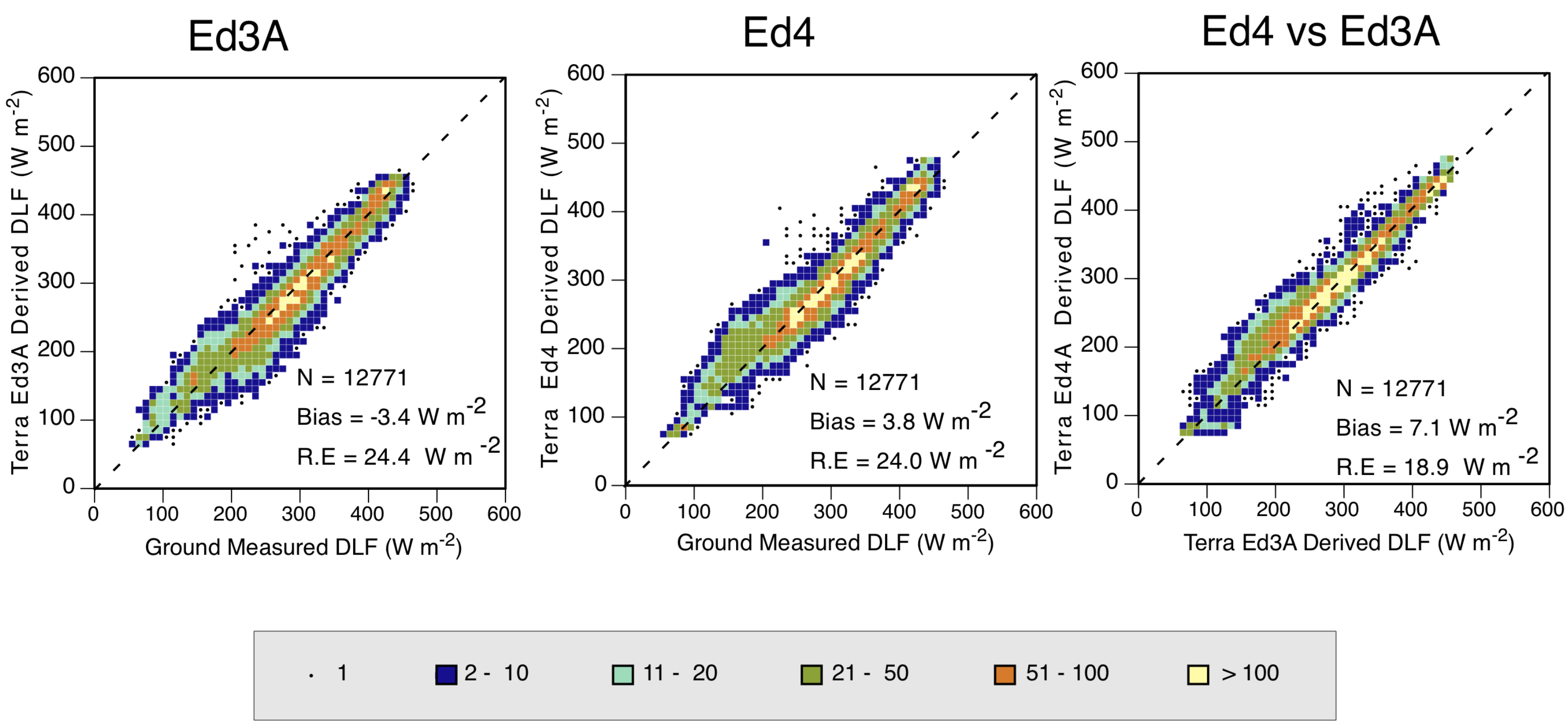
For conditions involving surface temperatures that are much below the overlying air temperatures (strong inversions), limiting the inversion to a maximum of 10K / 100hPa for the downward flux calculations provides the best results for all conditions for both MOA and CWG T_s.

The CWG skin temperatures have a significantly greater dynamic range than the MOA surface temperatures.

The use of the CWG skin temperatures will, therefore, tend to have a wider range of fluxes at the surface. Constraining the CWG and MOA surface temperatures using the SOFA methods, however, tends to yield comparable results.

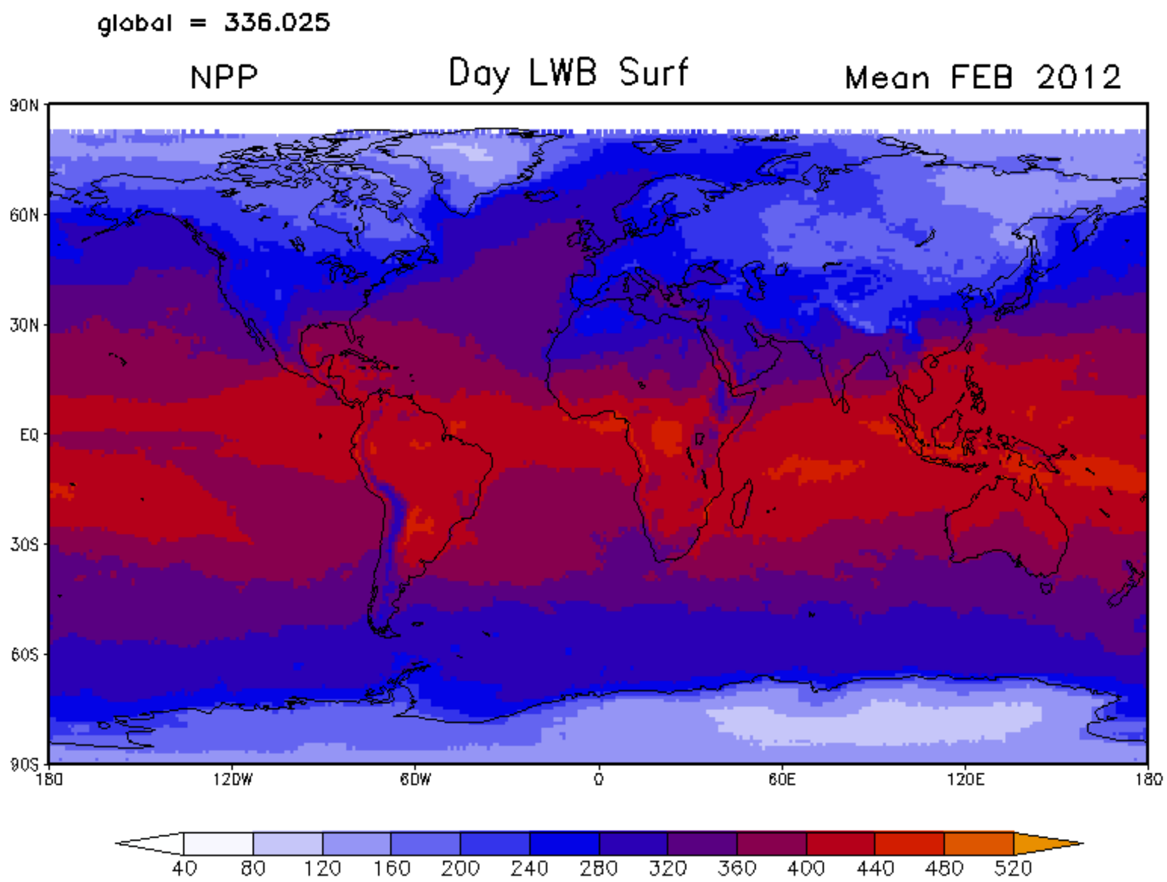
Edition 4 inputs into the LW model are providing the expected results.

Global 2004 Terra LWB Ground Validation



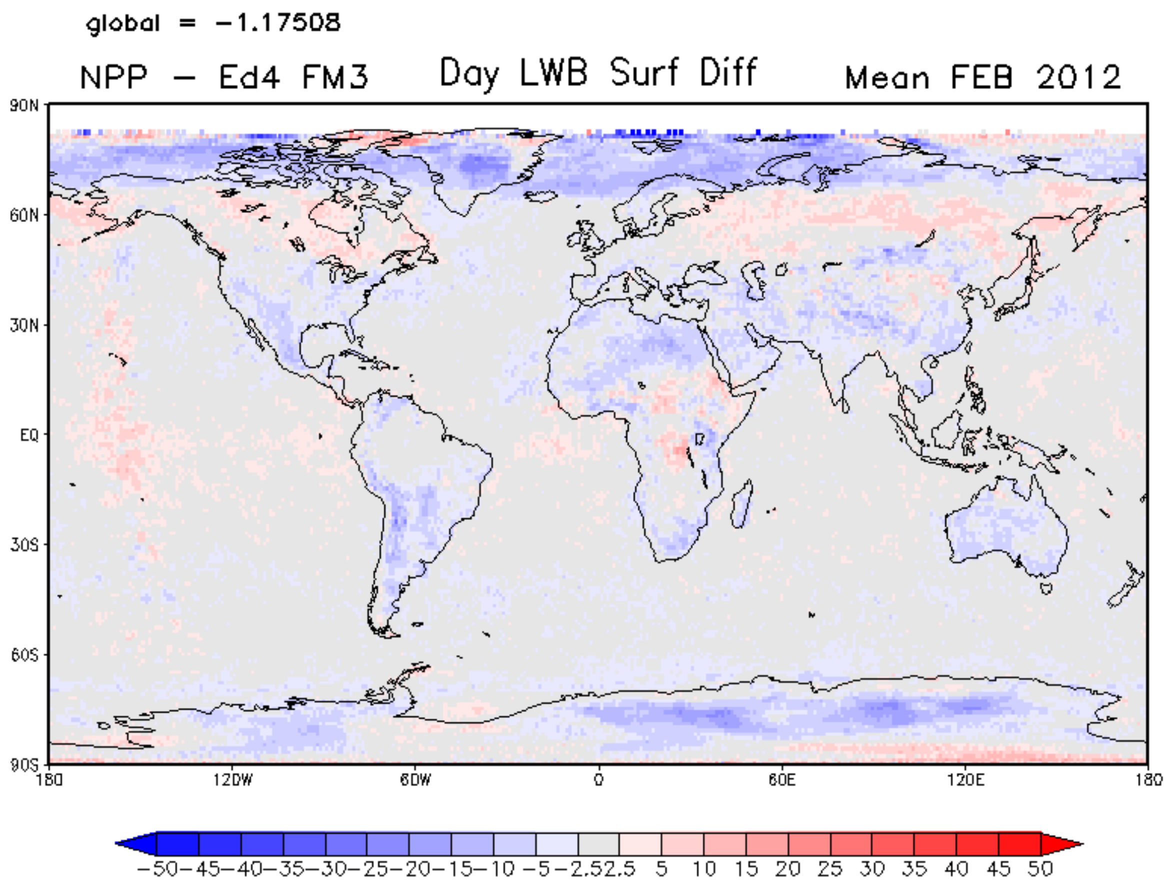
While there are differences in LWB footprint results due to differences in the input data, overall the stats changed little over the globe for the year.

LWB Daytime Surface Fluxes from NPP FM5



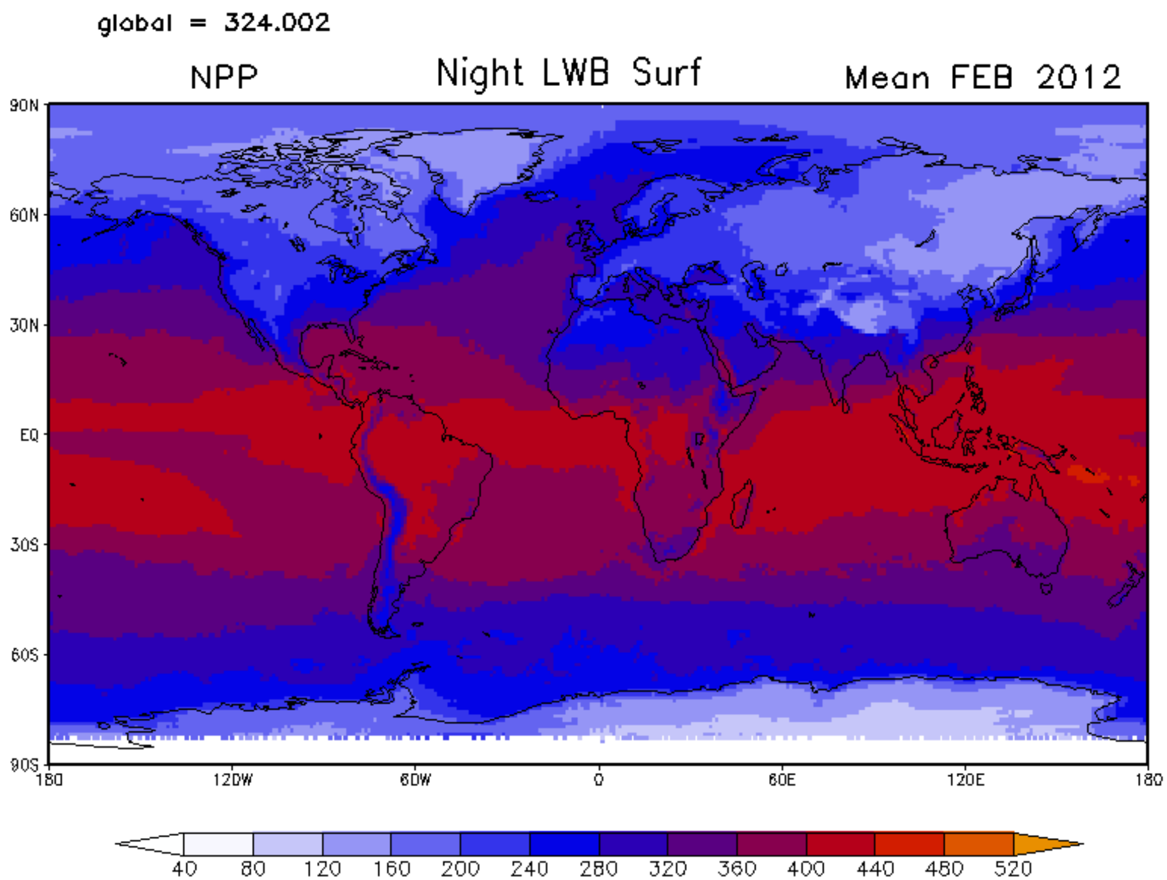
NPP FM5 LWB surface fluxes day

LWB Day Surface Differences NPP FM5 minus Aqua FM3



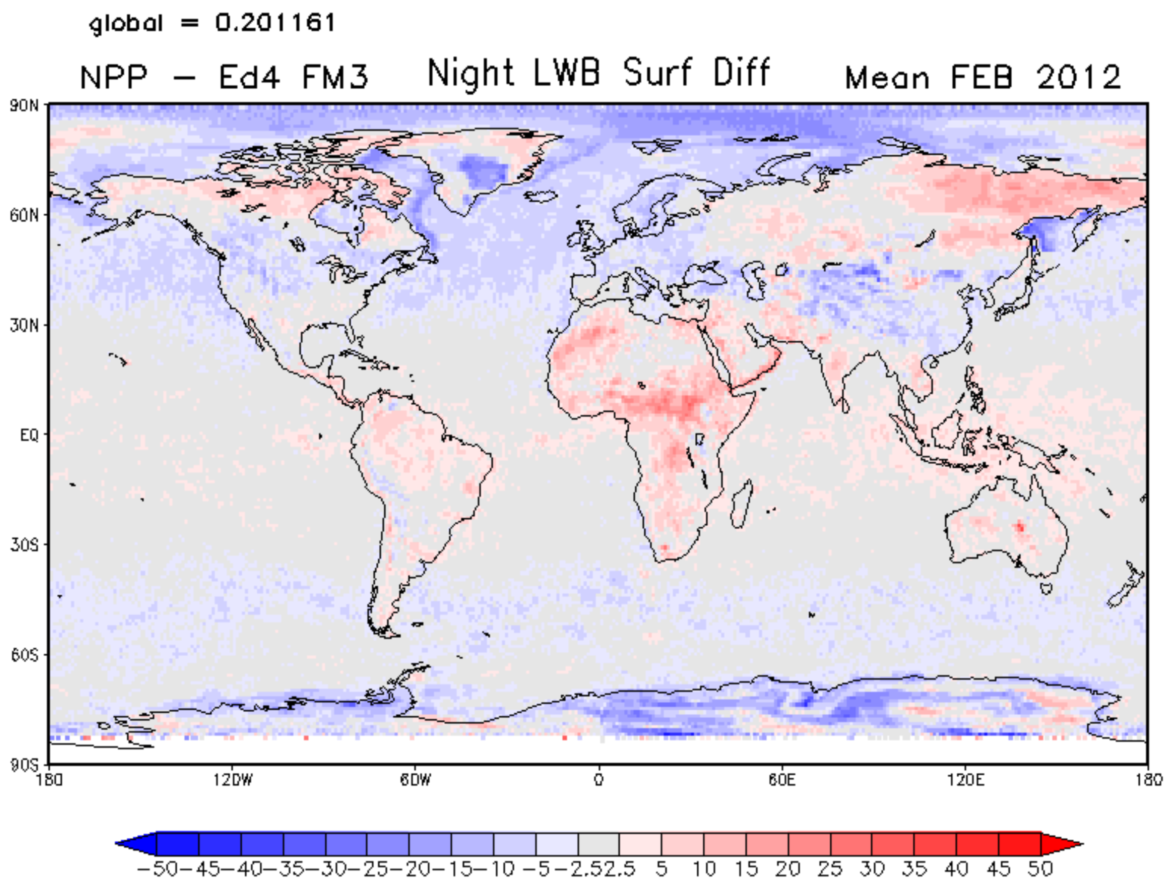
Differences between FM5 and FM3 LWB surface fluxes day

LWB Nighttime Surface Fluxes from NPP FM5



NPP FM5 LWB surface fluxes night

LWB Night Surface Differences NPP FM5 minus Aqua FM3



Differences between FM5 and FM3 LWB surface fluxes night

Recent and Future Improvements to the Surface-Only Flux Algorithms

SW Model Improvements: 1) Replacing the ERBE albedo maps with Terra maps greatly improved the SW retrievals, most notably for polar regions. 2) Replacing the original WCP-55 aerosols properties with monthly MATCH/OPAC datasets while also replacing the original Rayleigh molecular scattering formulation with the Bodhaine et al. (1999) model significantly improved SW surface fluxes for clear conditions. 3) To account for the short term aerosol variability we have incorporated daily MATCH aerosol data into Edition 4. 4) Using a revised empirical coefficient in the cloud transmission formula has improved the SW surface fluxes for partly cloudy conditions. 5) Work continues on the improvement of the cloud transmission method for the new Edition 4 clouds.

LW Model Improvements: 1) Constraining the lapse rate to 10K/100hPa (roughly the dry adiabatic lapse rate) improved the derivation of surface fluxes for conditions involving surface temperatures that greatly exceeded the overlying air temperatures, see Gupta et al. (2010). 2) Limiting the inversion strength to -10K/100hPa for the downward flux retrievals provided the best results for cases involving surface temperatures that were much below the overlying air temperatures (strong inversions).

SW and LW Model Improvements: 1) The availability of ocean buoy measurements is expected to allow for improved surface flux retrievals by providing validation over ocean regions.

Parameterized models for fast computation of surface fluxes for both CERES and FLASHFlux

Dataset	CERES 2B	CERES 4 Future
Clear-Sky TOA albedo Terra	48 month ERBE	70 month Terra
Clearr-Sky TOA albedo Aqua	46 month Terra	70 month Terra
Clear-Sky Surf. albedo	46 month Terra	70 month Terra
TOA to Surface albedo transfer	Instantaneous	Monthly average
Spec. Corr. Coef.	CERES 2B	CERES 3A
Cos (sza) dependence of Surface Flux	LPSA	Briegleb-type
Cloud Algorithm Terra	Terra Ed2	Terra/Aqua Ed4
Cloud Algorithm Aqua	Aqua Ed2	Terra/Aqua Ed4
SW aerosol dataset	WCP-55	MATCH/OPAC
Rayleigh Treatment	Original LPSA	Bodhaine et al (1999), JAOT.
Ozone Range Check	0 to 500 DU	0 to 800 DU
Twilight cutoff		New
Cloud transmission empirical coefficient	0.80	Cloud Transmission Tcod/Tccp Lookup
LW high temperature surface correction	No	Maximum Lapse Rate 10K/100hPa
LW Inversion correction	No	Maximum Inversion Strength -10K/100hPa

Lookup table to compute the SW Cloud Transmission as a function of total cloud optical depth (Tcod 0 to 75) and total cloud cover percent (Tccp 0 to 100)

Tccp Tcod	0.5	5.5	15.0	25.0	35.0	45.0	55.0	65.0	75.0	85.0	94.5	99.5
0.5	1.000	0.996	0.987	0.977	0.967	0.955	0.945	0.932	0.919	0.905	0.884	0.870
1.5	0.999	0.992	0.975	0.959	0.940	0.921	0.900	0.880	0.857	0.837	0.809	0.801
3.5	0.999	0.985	0.955	0.926	0.896	0.865	0.835	0.804	0.773	0.742	0.707	0.690
7.5	0.998	0.975	0.926	0.881	0.835	0.790	0.745	0.700	0.655	0.612	0.573	0.548
15.0	0.998	0.958	0.891	0.830	0.790	0.736	0.678	0.623	0.564	0.512	0.455	0.409
25.0	0.997	0.928	0.821	0.732	0.746	0.677	0.607	0.535	0.499	0.434	0.362	0.294
35.0	0.997	0.912	0.711	0.656	0.652	0.553	0.568	0.484	0.429	0.389	0.308	0.236
45.0	0.999	0.888	0.755	0.714	0.547	0.569	0.548	0.474	0.420	0.339	0.279	0.196
75.0	0.998	0.850	0.619	0.638	0.623	0.551	0.501	0.451	0.339	0.315	0.218	0.138

Frequency of occurrence in the Lookup table used to compute the SW Cloud Transmission as a function of total cloud optical depth (Tcod 0 to 75.0) and total cloud cover percent (Tccp 0 to 100)

Tccp Tcod	0.5	5.5	15.0	25.0	35.0	45.0	55.0	65.0	75.0	85.0	94.5	99.5
0.5	11280	24730	15686	13073	11707	10617	9703	8765	8034	7709	8564	8677
1.5	3955	11381	9552	9357	9748	10373	11135	12019	13298	15168	19492	16945
3.5	2229	7459	6321	6472	7082	8395	10677	13225	17981	27446	52192	53296
7.5	1876	4145	2843	2701	2782	3328	4037	5360	7531	12722	36686	70092
15.0	124	247	235	256	322	433	625	954	1638	3113	11630	53090
25.0	6	25	34	29	29	31	41	70	133	280	1734	15937
35.0	6	9	7	4	9	14	13	14	39	76	499	7213
45.0	3	8	4	2	3	12	10	6	10	26	210	4015
75.0	14	15	13	14	4	9	11	13	14	24	205	6548

Note, a low frequency of occurrence tends to produce a higher degree of uncertainty. Thus, cases with a high frequency of occurrence should be weighted more heavily.

Results of Recent SW Model Development (Course of Action for the Future)

A look-up table of cloud transmission was developed in terms of total cloud amount and total cloud optical depth using 1°x1° gridded hourly parameters from Synoptic Intermediate (SYNI) files for 12 months of 2004.

These parameters include: 1) All-Sky Surface SW Fluxes, 2) Clear-Sky Surface SW Fluxes, 3) Total Cloud Amounts, and 4) Total Cloud Optical Depth. Cloud transmission dependence on solar zenith angle was also examined and found to be very weak.

Use of this cloud transmission table at instantaneous footprint level resulted in significant underestimation of surface fluxes.

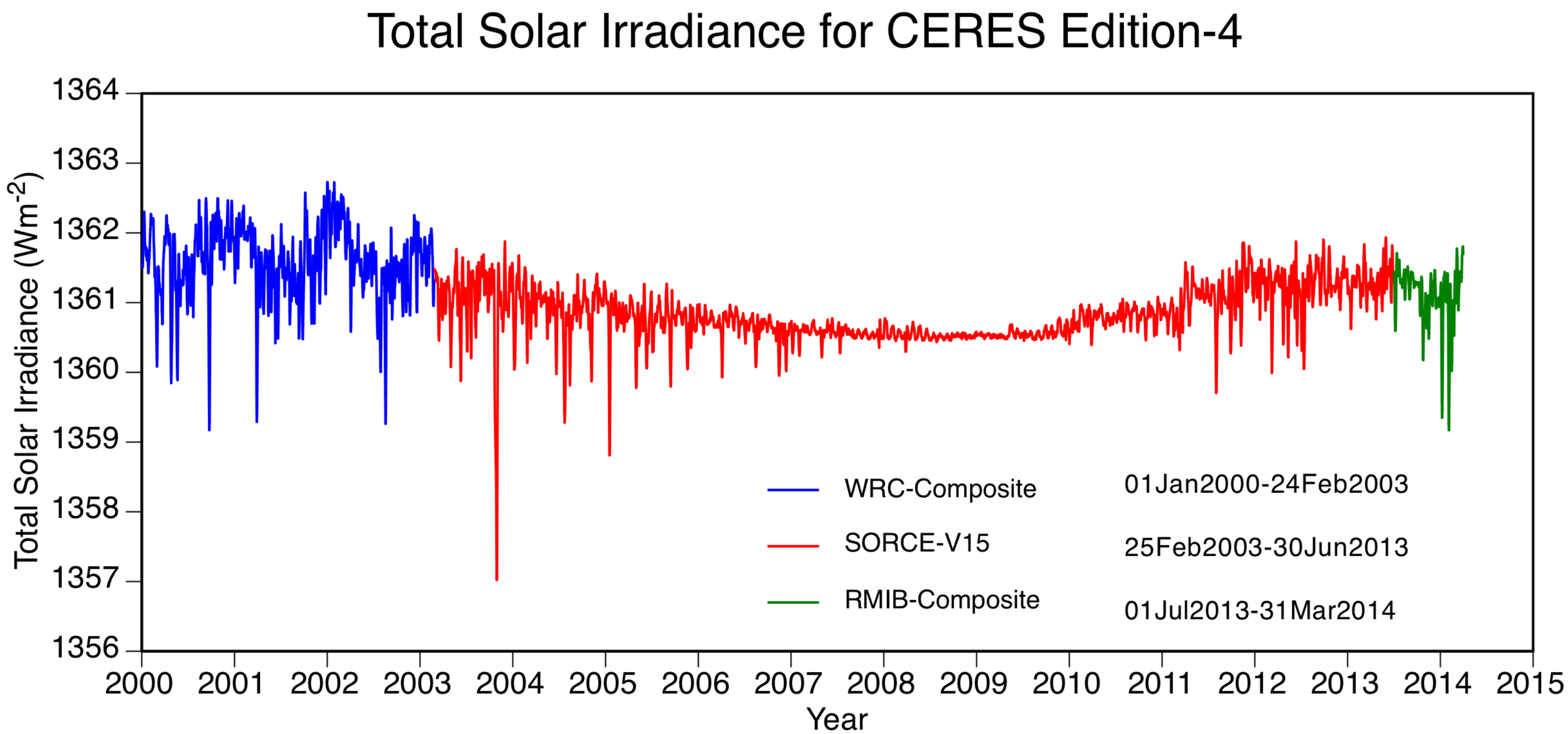
We have since revised our strategy to examine the possibility of using regression fits based SYNI data.

Conclusions for SOFA Ed4 algorithms

Previous validation studies have demonstrated that revisions to both the LW algorithms and the SW algorithms (for clear to partly cloudy conditions) appear to be working well, though further revisions to the cloud transmission method and/or overcast albedo method are needed for SW Model B. Currently, our attention is focused on deriving a regression fit to the data.

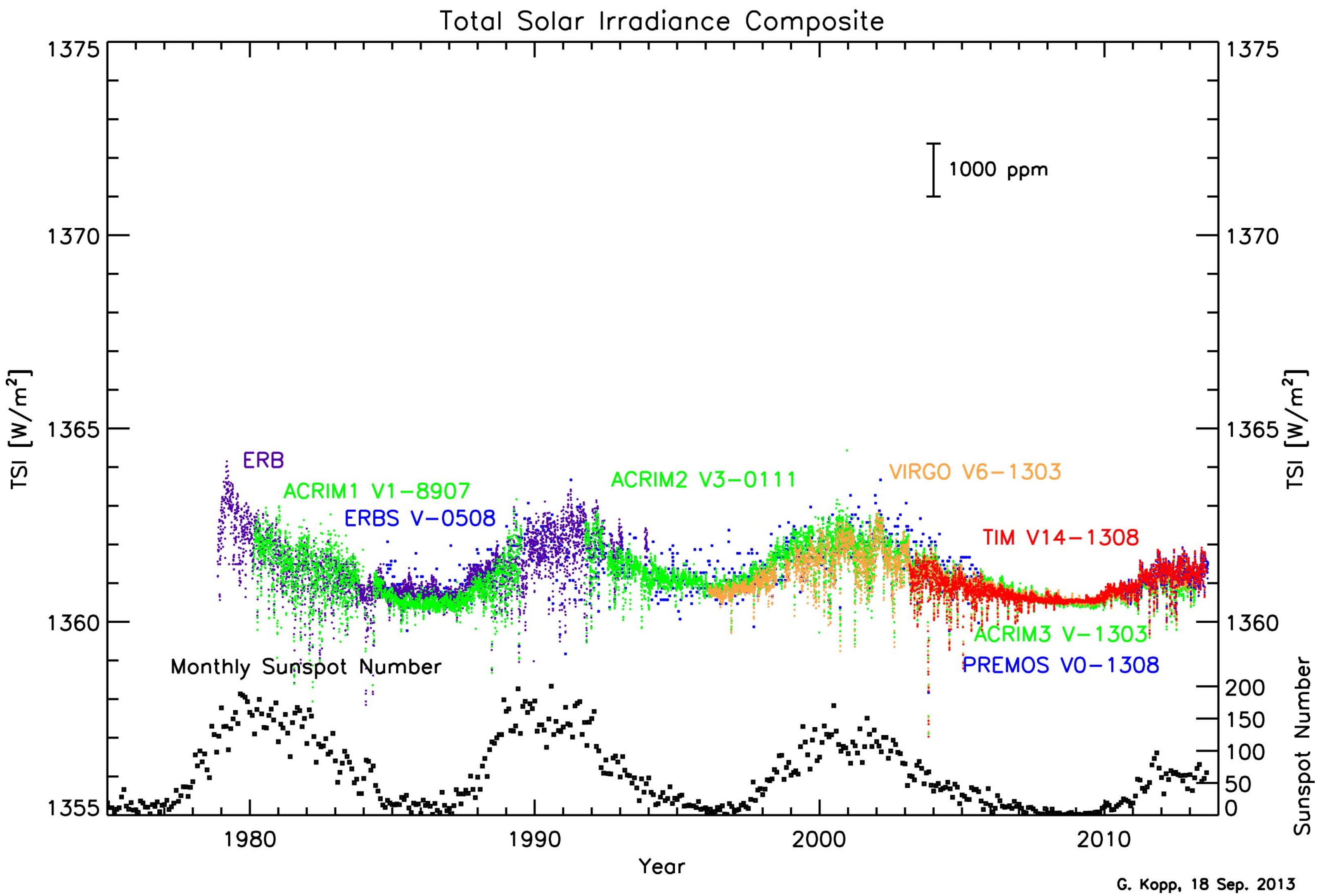
A preliminary analysis of the LW and SW surface only flux algorithm results using the Edition 4 inputs, especially those from the Clouds Subsystem, indicate improved accuracies for most locations.

TSI composite data from WRC, SORCE and RMIB for the Timeframe of CERES Terra, Aqua & NPP



Backup Slides

Total Solar Irradiance Database normalized to TIM V14



Climate Science Branch, NASA Langley Research Center

Status of Total Solar Irradiance Measurements (1)

The Total Irradiance Monitor (TIM) aboard the SORCE satellite has been measuring the Total Solar Irradiance (TSI) since 2/25/2003. This spectrally integrated solar radiation incident at the top of the Earth's atmosphere is incorporated into the CERES processing as CERES SSF-38a.

To continue the TSI measurements beyond the lifetime of the SORCE spacecraft, a copy of the TIM instrument was included in the manifest on the Glory spacecraft, which was launched on 3/4/2011; however, a failure of the payload fairing resulted in the loss of the Glory spacecraft.

To prevent a potential data gap, the Laboratory for Atmospheric and Space Physics (LASP) then provided the flight-spare of the TIM instrument to the U. S. Air Force for use in their Space Test Program (STP) Standard Interface Vehicle (SIV) program.

Status of TSI Measurements (2)

With the malfunction of the CPV6 battery cell on SORCE, TIM and the other instruments were powered off July 30, 2013.

Since the SORCE TIM TSI data were no longer available on a regular basis after July 2013, we began acquiring the RMIB composite TSI data from Steven DeWitte, who is providing the DIARAD VIRGO data with a latency of a few weeks to a month. The RMIB data, however, requires an offset from the DIARAD VIRGO mean low value of 1363 W/m^2 to match the SORCE mean low value of 1361 W/m^2. Note, for CERES Ed4, all TSI data are offset to match the SORCE TSI Version 15.

The TSI Calibration Transfer Experiment (TCTE) instrument was integrated into the STPSat3 satellite, along with 4 other satellite instruments, and was delivered to the Wallops Flight Facility in Virginia on 9/6/2013 and launched into orbit on 11/19/2013.

Status of TSI Measurements (3)

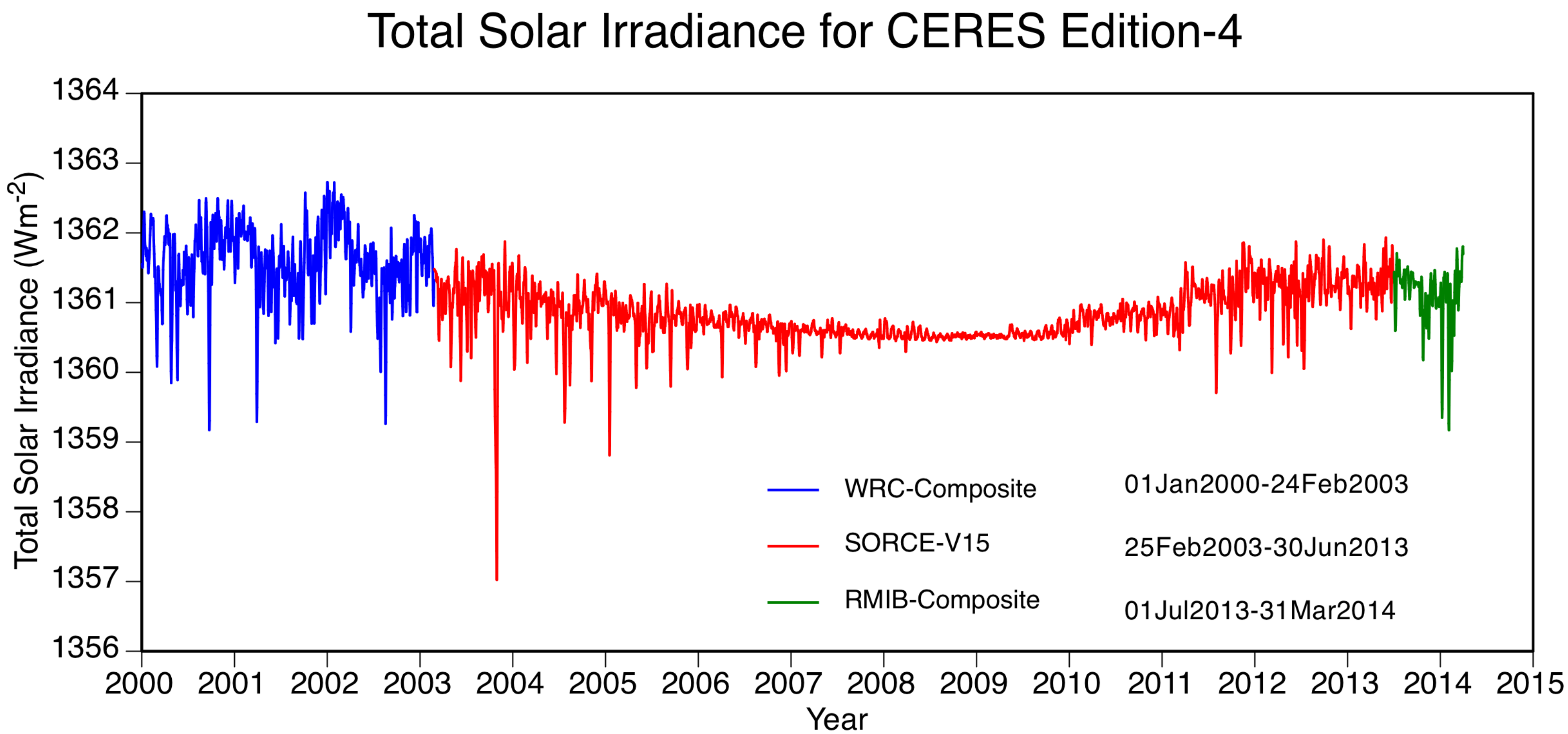
Projected Lifetime for the STPSat3 mission is 18 months though STPSat1 was launched on 3/8/2007 and remained operational until 10/7/2009 and STPSat2 was launched on 11/19/2010 and remained operational as of the last update on 01/24/2014.

Note: there may be a significant time delays before the U. S. Air Force declassifies the data taken by the STPSat3 instruments.

The TIM on SORCE was reactivated for a 1-week campaign (22-28/12/2013) to acquire overlap data with the recently launched (11/19/2013) TCTE instrument on STPSat3.

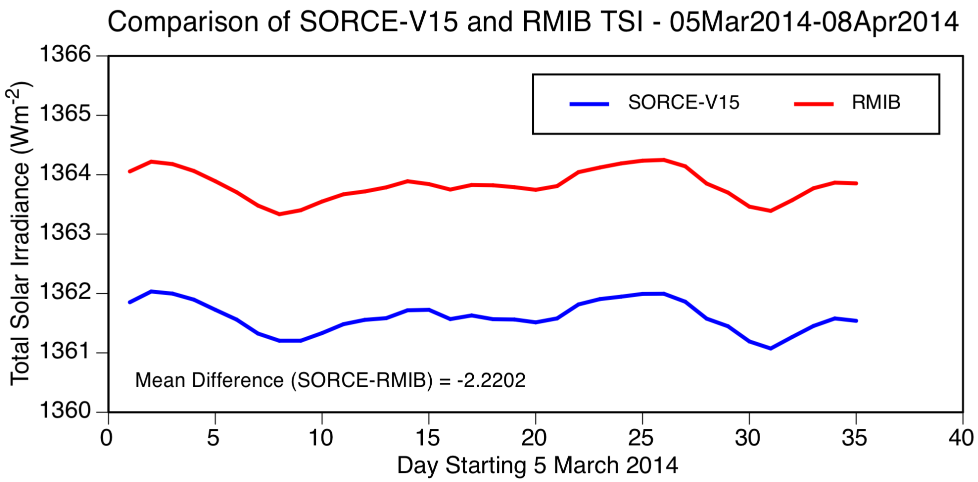
On 2/24/2014 the SORCE Operations Team implemented a new operational mode (powering down during eclipse/night) to acquire TSI data. Beginning with 3/5/2014 the TSI data is being produced continuously with a 7 day latency.

TSI composite data from WRC, SORCE and RMIB for the Timeframe of CERES Terra, Aqua & NPP

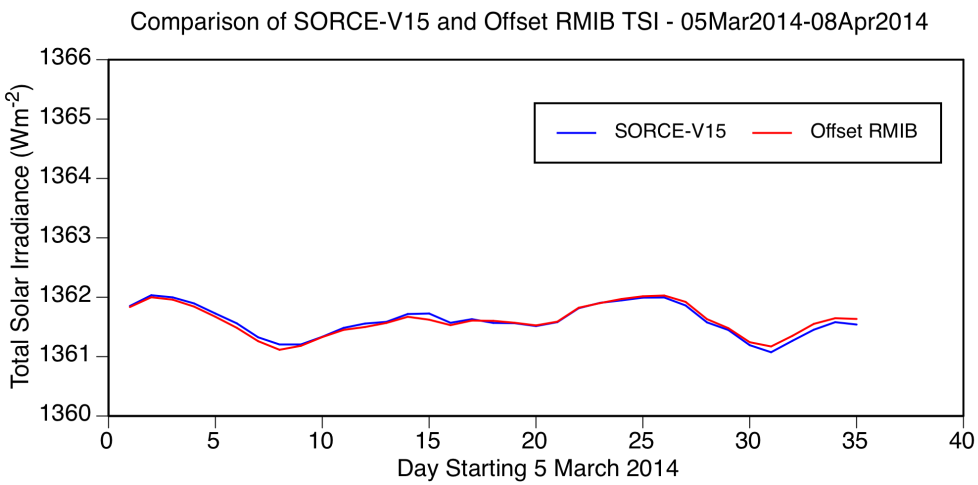


Climate Science Branch, NASA Langley Research Center

Comparison of SORCE-V15 and RMIB TSI 3/5-4/8 2014



For this 35 Day Period SORCE – RMIB $= -2.2202\ Wm^{-2}$



RMIB offset to same scale as SORCE

The future of TSI Measurements

The Total Solar Irradiance Sensor (TSIS) has NOT been included on either of the first two JPSS mission, thereby increasing the possibility of a gap in the TSI data record.

The current instrument manifest for JPSS-1 is:

Visible Infrared Imaging Radiometer Suite (VIIRS)

Cross-track Infrared Sounder (CriS)

Advanced Technology Microwave Sounder (ATMS)

Ozone Mapping and Profiler Suite (OMPS-N)

Cloud and the Earth's Radiant Energy System (CERES-FM6)

The current instrument manifest for JPSS-2 is:

VIIRS, CriS, ATMS & OMPS

CERES Journal Publication Citations

For all publications whether funded by CERES or using CERES data, please include the word "CERES" in the keyword list as this will facilitate listing your publication in the CERES formal publication web-page list (http://ceres.larc.nasa.gov/docs.php).

When any paper, technical report, or book chapter has either been accepted for publication or been published, please notify the CERES group of this publication by contacting Anne Wilber at (anne.c.wilber@nasa.gov).

CERES Journal Publication Citation Values (4/1/2014)

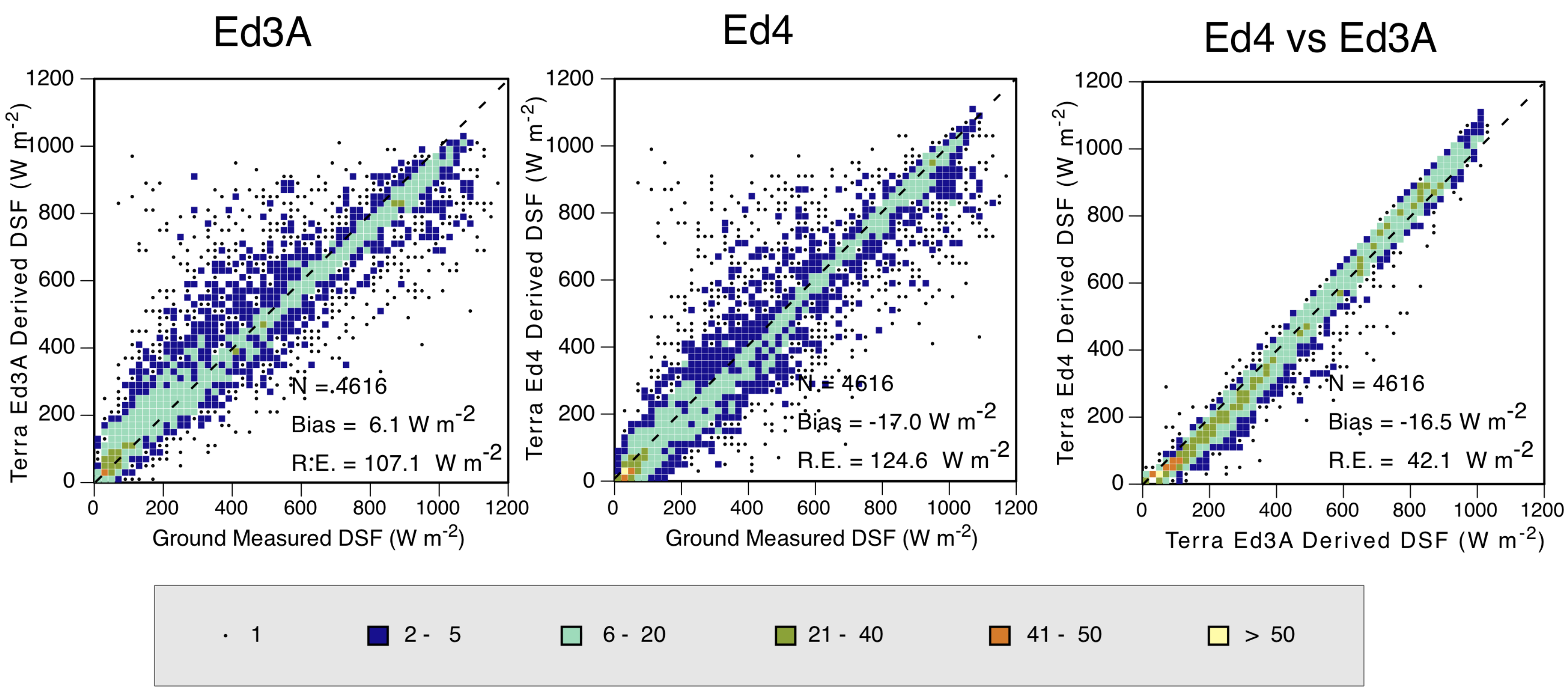
			c1	c2	c3
Year	All References[1]	Journal Articles[2]	Citation[3]	Citation[4]	Citation[5]
2014	52	14	1	242	532
2013	96	96	199	1760	3869
2012	80	77	351	1418	3117
2011	63	63	901	1430	3144
2010	65	63	1141	1219	2680
2009	49	49	1200	1056	2321
2008	62	61	1077	888	1952
2007	39	31	839	720	1583
2006	44	40	1647	515	1132
2005	49	47	1812	456	1002
2004	39	38	1443	344	756
2003	51	48	1835	327	719
2002	78	69	5177	303	666
2001	50	44	2041	179	394
2000	34	32	1069	179	394
1999	24	21	731	126	277
1998	20	20	2172	56	123
1997	9	9	296	33	72
1996	5	5	792	17	38
1995	1	1	17	4	9
1994	1	1	3	1	2
1993	6	6	38	0	0
Total	917	835	24782	11273	24782

Citation c1 = # of citations for papers published in that year.

Citation c2 = # of citations in ISI for papers published in all years using a specified set of categories.

Citation c3 = renormalized # of citations for papers published in all years so that the total number of citations in c3 = c1

Global 2004 Terra SWB Ground Validation



These results show the changes in Clouds, ADMs and the SOFA SWB Model (WCP55 to MATCH aerosols, new Rayleigh, new Cloud Transmission)